

# DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

## UNITED STATES AIR FORCE

### METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather (HQ USAF/XOW), within the HQ USAF, Deputy Chief of Staff for Air and Space Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication 0-2) document. HQ USAF/XOW interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

The Air Force Weather Agency (AFWA) is a field operating agency (FOA) reporting to HQ USAF/XOW. The AFWA provides centralized weather support to designated users. The AFWA has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) and the Air Force Combat Weather Center (AFCWC). Air Force Space

Command provides space environmental support through the 55th Space Weather Squadron (55 SWXS).

Observations. Meteorological observations are classified as surface, upper air, radar, or satellite observations. Observation and sensing of the space

environment are discussed in the Space Environmental Services section.

Surface observations are taken by Air Force personnel to support military operations and for weather analysis and forecasting. Observations from both Air Force and Army locations

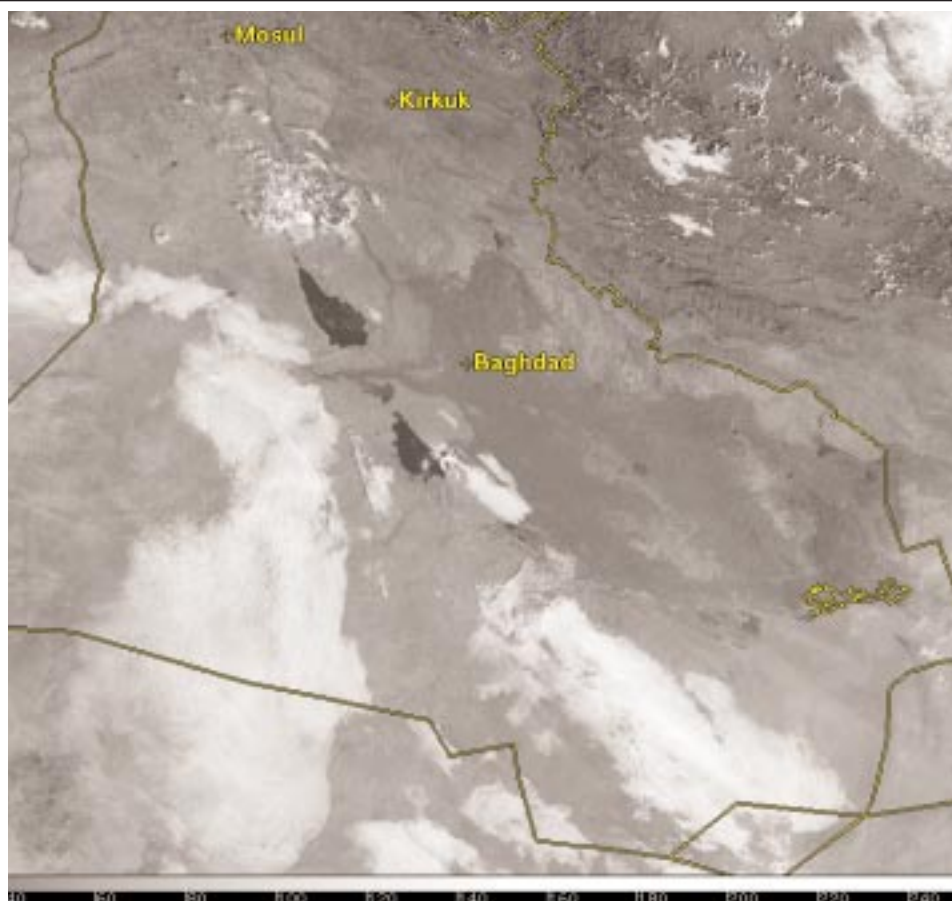


Figure 3-DOD-1. DMSP imagery of cloud cover over Iraq.

(fixed and tactical) are made available to local users and are transmitted to AFWA and to other military and civil locations throughout the world.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information comes from United States and foreign rawinsonde sources and military and civilian satellite-derived data. Additional upper air information is obtained from military and civilian pilot reports.

Weather radar is a principal source of information for providing warnings of severe weather. Many of the radars are part of the United States basic weather radar network or are used to support the National Hurricane Operations Plan. The tactical weather radars are used to support contingency operations. The Air Force is evaluating concepts for a tactical Doppler weather radar which could operate in both mobile and fixed locations.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single source of global weather data used for combat support. On-board sensors provide AFWA, 55 SWXS, and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, auroral electron counts, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses an operational linescan system. The visible detectors were selected to optimize distinction among clouds, ground, snow, and water. It uses both stellar and inertial references, together with on-board processors, to maintain stability and pointing

accuracy. The DMSP also flies a microwave temperature and humidity sounder (SSM/T, SSM/T-2) which provides vertical temperature, moisture, and height profiles of the atmosphere. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications. The Air Force communications system uses a variety of media to meet the needs of its worldwide customer base. Asynchronous Transfer Mode (ATM) fiber optic networks are used to distribute high-resolution satellite imagery and forecast data from global numerical weather prediction models between large DOD and civilian processing centers. Commercial T-1 circuits provide a subset of this data to new theater and regional forecast facilities. Forecaster-developed products and gridded data sets are distributed from HQ AFWA via the Communications Front End Processor to base and post weather stations using dedicated 9600-baud circuits. These dedicated circuits are now augmented by, and will eventually be replaced by commercial Ku-band broadcast satellites over the CONUS, Europe, and the Pacific. The broadcast satellites now provide tailored satellite and Next Generation Doppler Radar imagery to the base and post weather stations at both fixed and deployed locations.

Alphanumeric data including synoptic, upper-air, and pilot reports are collected and distributed via the Automated Weather Network (AWN). The AWN is a collection of dedicated circuits ranging from 74-baud to 56kbps linking DOD, national and international facilities worldwide. Data is also received from DOD-operated High Frequency (HF) radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological

Organization (WMO) channels. The Automatic Digital Weather Switch at Tinker AFB, Oklahoma receives alphanumeric weather data and Notices to Airman (NOTAMs), parses them according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are re-distributed to end users over (1) the same dedicated circuits, (2) the DOD's Non-secure Internet Protocol Network (NIPR-NET), and (3) HF and satellite broadcast facilities. End-user systems include the Automated Meteorological Information System (AMIS), Meteorological Information Standard Terminal (MIST) and small computers using a variety of alphanumeric display packages.

Preparation of Analyses and Forecasts. The primary center for providing weather analyses and forecasts for Air Force and Army operations is AFWA at Offutt AFB, Nebraska. AFWA uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFWA and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFWA also provides backup for the National Weather Service

(NWS) Storm Prediction and Aviation Weather Centers.

In support of DOD combat operations, Air Force Weather (AFW) operates centralized units consisting of AFWA, AFCCC, 55 SWXS, fixed theater Forecast Units (FU), fixed Weather Support Units (WSU), and provides personnel to deployed Joint Meteorological/Oceanographic (METOC) Operations Centers (JMOC). AFWA has reengineered forecast operations to achieve greater flexibility and focus production on its primary customers. Forecasts are generated in the agency's Global Weather Center Division, which consists of four production branches: the Forecast Production Branch, the Special Support Operations Branch (SSOB) which was formed through combining the Special Operations Forces Weather Operations Center (SOFWCC) and the CINC Target Weather Forecast Cell (CTWFC), the National Programs Operations Branch (NPOB), and the Satellite Applications Branch.

The Global Weather Center Production Branch produces tailored worldwide meteorological analyses and forecasts in support of strategic aviation customers. The branch provides specific point weather warnings for Air Force and Army installations in the CONUS; dedicated, worldwide, broadcast-quality public weather services and planning forecast support through the American Forces Television Network to DOD personnel and family members stationed overseas; and hot backup to Aviation Weather Center and Storm Prediction Center. The branch also provides forecasts of CONUS low-level aviation hazards.

The Special Support Operations Branch provides worldwide mission-tailored forecasts to the Special Operations Forces (SOF). The branch acts as a clearinghouse for unique data requests from the SOF customers; provides end-to-end targeting support to unified command, component, or

national customers; produces long-range (4-10 day) forecasts to unified command, component, or national customers; and supplies the Nation's reconnaissance cloud-free forecast products.

The National Programs Operations Branch provides weather support for classified National Programs directed by the Secretary of the Air Force. The branch identifies and documents weather service requirements and initiates actions to ensure Sensitive Compartmented Information (SCI) and Special Access Program (SAP) weather supports needs are met. It serves as

focal point for AFWA SAPs; ensures National Program and other SCI and SAP support requirements are integrated into AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to national programs; and interfaces with the DOD and national intelligence community regarding weather services and exploitation of weather information.

The Satellite Applications Branch provides rapid response tailored METSAT imagery and evaluation for DOD contingency mission support. The branch produces detailed global cloud analyses to update, and refine the Real Time

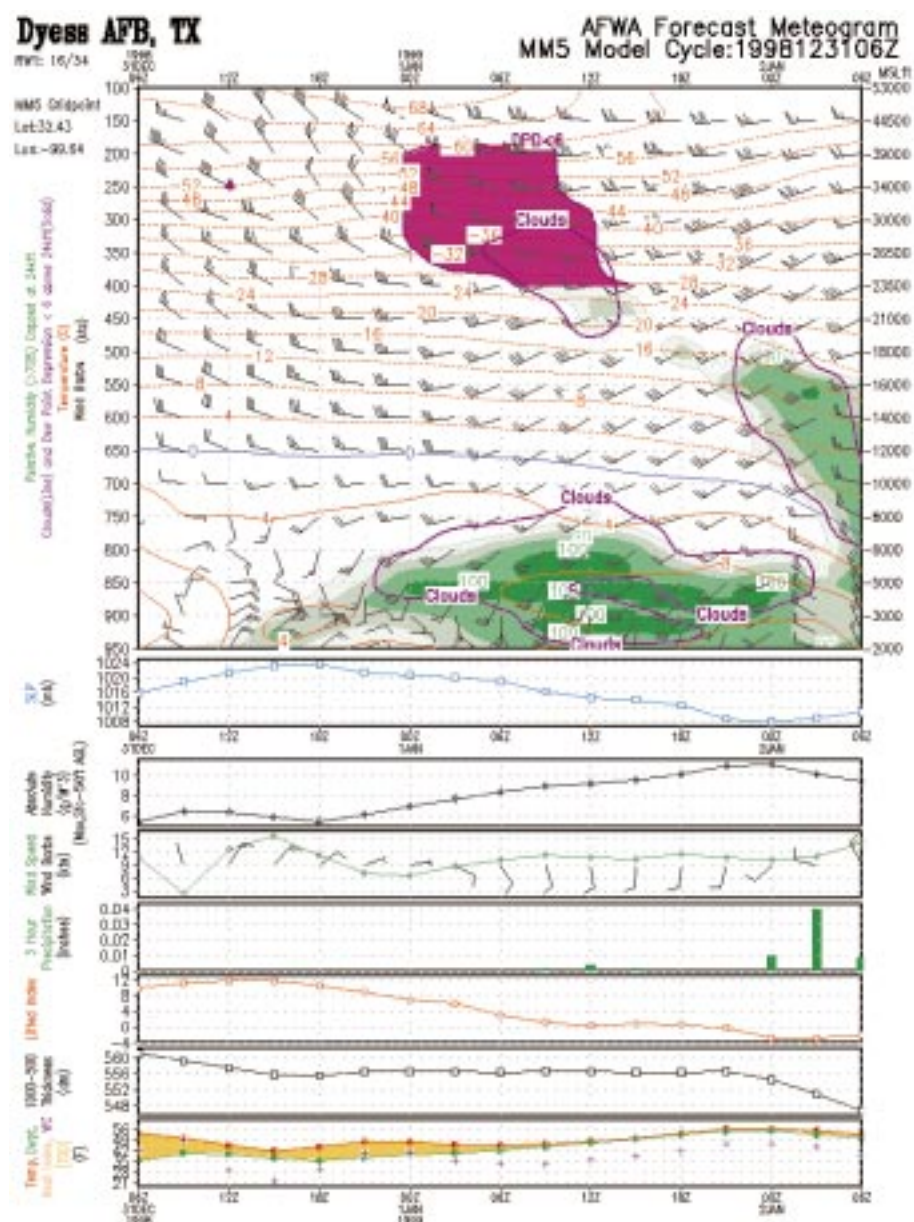


Figure 3-DOD-2. 48-hour Meteogram for Dyess AFB, Texas.

Nephanalysis (RTNEPH) database; produces global snow and ice cover analysis to update and refine the Snow Depth (SNODEP) database; and generates automated METSAT imagery products for AFWIN/SAFWIN distribution to DOD customers. The branch also tracks and classifies tropical cyclones (METSAT analysis) for DOD Joint Typhoon Warning Center (JTWC) and other United States Tropical Cyclone Warning Centers; provides hot back up for JTWC satellite operations; and monitors operational status, evaluates quality of imagery ingested at AFWA. It coordinates corrective actions; maintains, modifies, develops new capabilities to display and visualize satellite imagery data on workstations; infuses state-of-the-art techniques into improved imagery analysis ensuring high quality customer products; serves as AFW focal point on technical issues regarding METSAT imagery utilization; and interfaces with the DMSP SPO, AFSPC and other DOD and governmental agencies on METSAT data exploitation issues.

Dissemination of Forecasts and Warnings. The Air Force and Army require worldwide meteorological services for specific operational and planning activities. Military users

require meteorological information directed to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations.

Air Force Weather enhances the unique global capability of military aviation while indirectly assisting civil aviation. Air Force personnel provide flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers. To fulfill this requirement, designated AFW personnel serve as part of the working staff of operational Air Force, Army, and joint force units. In this capacity, AFW personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. This effort helps ensure that Air Force, Army, and joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission needs.

Deployed weather teams are the basic units providing weather support in a combat theater. These teams provide surface and upper air observations, staff weather officer (SWO) services, and forecasts. The tactical forecast system, tactical weather radar, tactical meteorological satellite direct readout terminals, and tactical communications terminals provide the means to acquire vital meteorological data within a theater. A high frequency radio broadcast (HFRB) system is used to augment transmission of alphanumeric and facsimile products to the theater weather force. The HFRB system consists of regional broadcast stations at Andersen AFB, Guam, Elkhorn, Nebraska, and Roosevelt Roads, Puerto Rico.

Specialized Support. AFCCC, Asheville, North Carolina, provides environmental data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFWA and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC is colocated with the National Climatic Data Center to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3D) cloud analysis extracted from meteorological satellite imagery (Real-time Nephanalysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force also supports an array of Air Force and Army specialized requirements. Some of these are described below:

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The



Figure 3-DOD-3. AF Special Operations Weather Team.

Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. AFW units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force also provides launch-forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate the Joint Typhoon Warning Center (JTWC) which recently moved to

Hawaii. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees longitude to the East Coast of Africa in both hemispheres.

The Air Force directly supports DOD Special Strategic Programs, the National Command Authority, the National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

The Air Force provides space environmental data, products, services, and solar forecasts to a wide variety of customers through the 55 SWXS at Schriever AFB, Colorado. An element of the 55 SWXS is colocated with NOAA's Space Environment Center in Boulder, Colorado.

The Air Force also provides agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

DOD Modeling and Simulation Executive Agent (MSEA) for the Air and Space Natural Environment (ASNE). The Director of Air Force Weather (AF/XOW) is the MSEA. The director executes his responsibilities through the Office Chief collocated at the Air Force Combat Climatology Center (AFCCC) in Asheville, North Carolina. The Executive Agent is responsible to ensure modeling and simulation developers and users have authoritative environmental models, algorithms, and data to represent the air and space environment rapidly, thoroughly, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence.

Air National Guard (ANG). There are two distinct functions within the ANG weather program. The traditional program consists of 33 weather

flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and United States Army Reserve (USAR) units as well as ANG flying units. A Weather Readiness Center operates at Camp Blanding in Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield operations.

Planned Enhancements. Air Force, Army, and joint force operational requirements for environmental support are the basis for all Air Force actions to improve existing or acquire new capabilities. The Air Force assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development. AFWA and the Naval Meteorology and Oceanography Command are working on initiatives to improve environmental support to joint and service operations. They focus on the strengths of each of the services and build on existing cooperative efforts.

The Air Force is modernizing and improving its strategic, operational, and combat level systems. Modernization programs include the Operational Weather Squadron (OWS) Production System, Phase 2 (OPS II), and the New Tactical Forecast System (N-TFS). N-TFS replaces the Automated Weather Distribution System (AWDS).

The OPS II system will serve as the backbone of future centralized support in AFW. This system provides the computer hardware and software necessary for the AFW Strategic Centers and OWSs to produce and disseminate forecast products to Combat Weather Teams (CWTs). Strategic Centers provide weather support at the global and synoptic-scale levels for their worldwide customers. At the OWS, fore-

casters have a theater-level focus and produce forecasts, weather warnings and advisories, planning and execution area forecasts and other operational products. The CWTs then tailor these centrally produced products for individual missions. The OPS-II is a hybrid system of databases, servers, and work stations. It serves as a clearing house of weather information allowing the forecaster to access any of the data and weather products in the AFW "data cloud".

N-TFS provides in-garrison and deployed personnel the meteorological tools necessary to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, command and control, and support forces worldwide. N-TFS provides weather personnel the ability to use the same system in "peace and war", thus providing a robust "first in" and sustainment weather forecast capability to combat weather units worldwide. Additionally, N-TFS will ingest data from Air Force observing systems and observations from indigenous sources.

Current and future weather observational systems include the Automated Observing System (AOS) for in-garrison operations, as well as the Manual Observing System (MOS). Other systems are the Tactical Meteorological Observing System Modification (TACMET MOD), the DMSP program's Small Tactical Terminal (STT), and the Tactical Weather Radar (TWR) in combat environments. These systems will provide deployed personnel the accurate observational data necessary to support warfighting operations.

The WSR-88D procured through the NEXRAD Joint System Program Office continues to be modernized, in concert with NOAA and FAA radars, to improve reliability and maintainability and keep technology current. It is operated and maintained by DOD,

NOAA, and FAA within the CONUS and by the Air Force overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS WSR-88D network will satisfy weather radar requirements in support of the general public, the military, and the aviation community.

The Cloud Depiction and Forecasting System (CDFS) II will make major software and hardware modifications at AFWA to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions to meet customer-stated requirements.

The MARK IVB Direct Readout program has procured new satellite receiver terminals to replace the aging MARK IIIs. In addition to providing high resolution satellite imagery from polar and geosynchronous weather satellites, the MARK IVB terminals accept and use data from the DMSP microwave imager and sounders and the TIROS microwave sounding units A and B. The MARK IVB produces both uniform gridded data fields and traditional meteorological products.

The Small Tactical Terminal (STT) is a small, lightweight, ruggedized, modularized, interoperable, first-in satellite receive terminal that receives data transmitted by geostationary and polar orbiting meteorological satellites. There are three configurations of the STT. The basic STTs receive low resolution DMSP and civil polar (TIROS, METEOR, etc.) data as well as WEFAX transmissions from geostationary satellites. The Enhanced STT adds the capability to receive and display high resolution DMSP and TIROS real-time broadcasts. Finally, the Joint Task Force Satellite Terminal adds the capability to receive high resolution, geostationary data.

STTs are being fielded at the lowest level of tactical weather operations (i.e., support to USAF flying squadrons and Army divisions). Furthermore, all STTs can be net-

worked through battlefield communication internets to create comprehensive satellite imagery distribution systems. Future developments in the STT program build on these initial capabilities to further reduce the size and weight of equipment and maximize use of the communication links on the battlefield.

Recently, the concept of operations for employing the STT has changed to better meet the needs of the Air Force's Expeditionary Aerospace Force concept. All STTs will be modified to accept the high resolution geostationary signal. Several STTs will be fielded without direct readout antennas and rely on battle-field common-user communications with other fully capable STTs in theater. Additionally, efforts are being made to retrieve real-time polar orbiting METSAT data through the STTs for use at AFWA.

## **SPACE ENVIRONMENTAL SERVICES**

55th Space Weather Squadron (55 SWXS) is the Air Force focal point for operational space environmental support. 55 SWXS also participates with NOAA in the joint operation of the Space Environment Center (SEC) in Boulder, Colorado. Under existing agreements, SEC and 55 SWXS provide limited backup for each other during contingencies. Many DOD systems operate in, or are affected by, conditions above 50 kilometers altitude. The space environment includes the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them, such as the sun and interplanetary space. 55 SWXS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems that operate in this environment. Space environment forecast products and/or specialized services are provided for the following:

- Ionospheric conditions.
- Energetic particle fluxes at satellite orbits.

- Solar flare, solar particle, and geomagnetic storm events.
- Upper-atmospheric density variations by providing geomagnetic and solar indices.
- High frequency (HF) radio wave propagation.
- Detailed post-analysis studies of operational system problems to determine if the space environment was a contributing factor.

The effects of the space environment on DOD systems are many and varied. The magnetosphere affects satellite operations through such phenomena as single event upsets (SEU) and spacecraft charging. Manned spaceflights are vulnerable to intense radiation from large solar flares and geomagnetic storms, particularly for high inclination orbits. Ionospheric conditions have a profound effect on the propagation of radio waves and radar signals, leading to communications blackouts and erroneous radar returns. Variations in the neutral atmosphere affect satellites orbiting at relatively low altitudes.

Sources of Space Environmental Data. To obtain solar data, the 55 SWXS operates a network of solar optical and radio telescopes. Solar Electro-Optical Network (SEON) observatories are located at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Haleakala, Hawaii, San Vito, Italy, and Learmonth, Australia. The 55 SWXS also receives real-time solar X-ray and

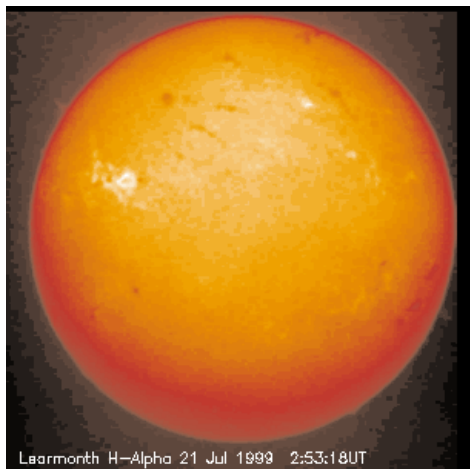


Figure 3-DOD-4. Solar Image.

energetic particle and geomagnetic data from the Geostationary Operational Environmental Satellites (GOES); DMSP, NOAA, and other DOD geostationary satellites provide additional energetic particle data in low-Earth and geosynchronous orbits. The 55 SWXS and NOAA SEC also exploit real-time solar wind data from the NASA Advanced Composition Explorer satellite currently one million miles sunward of the earth at the L-1 Lagrangian point.

A world-wide (primarily Northern Hemisphere) network of ionosondes and polarimeters provides ionospheric data. AFW has deployed the automated Digital Ionospheric Sounding System (DISS) to replace older instruments and provide improved ionospheric coverage.

The 55 SWXS monitors variations of the geomagnetic field using ground-based magnetometers through a cooperative agreement with the USGS, computes a real-time geomagnetic index, and transmits the derived index to users.

Warning and Forecast Services. In near-real-time, 55 SWXS provides operators advance warning of conditions that could degrade performance of their systems. Notifications include:

- Solar X-ray events which can disrupt HF communications on sunlit paths.
- Solar radio bursts which can disrupt communications systems and interfere with radar systems.
- Solar proton events which can produce radiation hazards to spacecraft and absorption of transpolar HF radio waves.
- Ionospheric disturbances which can degrade HF and satellite communications systems.
- Geomagnetic disturbances which can affect the orbital parameters of low altitude satellites, cause spacecraft charging and/or physical damage, disrupt HF radio wave propagation, or interfere with radar systems.

Future Improvements in 55 SWXS Support. 55 SWXS is enhancing its ability to observe the space environment, analyze data, and model the near-Earth environment.

The Ionospheric Measuring System (IMS) is a planned replacement for the current polarimeter network. IMS, using signals from Global Positioning System (GPS) satellites, will measure total electron content. The initial purchase and deployment of five IMS units is in progress.

The SEON Solar Maximum Modification will improve the capabilities of the SEON observatories. Efforts continue to upgrade obsolete and non-supportable equipment to maintain current capability.

A series of Solar X-Ray Imagers (SXI) will be flown beginning on the next GOES satellite launched. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. These data will be downlinked to the SEC and transmitted to 55 SWXS in real-time.

The Solar Wind Interplanetary Measurements (SWIM) is an Air Force Research Laboratory investigation using data from NASA's WIND research satellite launched on 1 November 1994. SWIM provides two hours of real-time interplanetary solar wind data to 55 SWXS each day. Additionally, there will be two campaigns a year during which real-time data will be provided 8 hours a day. The expected life of SWIM/WIND is 5 to 7 years.

Solar Radio Burst Locator (SRBL). This new ground-based system is projected to be operational in 1999. SRBL radio mappings of active regions on the solar disk will augment the present optical observations of these phenomena that are limited by clouds and other atmospheric obscuring factors. Precise location of active regions on the solar disk is crucial to accurate forecasting of solar flare impacts on the near-earth environment.

The Space Environmental Technology Transition (SETT) program transitions state-of-the-art space environmental models to operational use at 55 SWXS. These models will specify and forecast the space environment from the Sun to the Earth's upper atmosphere. The output of these models will drive specific application programs tailored to customer needs. The transition of the SETT models to the 55 SWXS will be complete by 1999. Follow-on model development will focus on improving model accuracy and will replace surrogate parameters (as model inputs) with direct measurements wherever possible.

- **Magnetospheric Models.** The Magnetospheric Specification Model (MSM) provides specification of magnetospheric particle fluxes at geostationary altitudes and precipitating particle fluxes in the auroral zone. An upgrade to this model, the Magnetospheric Specification and Forecast Model, will provide forecast capability and increase the MSM coverage area. One application of MSM output will be as input for satellite anomaly programs. The MSM became operational at the 55 SWXS in FY 1995.
- **Ionospheric Models.** The Parameterized Real-Time Ionospheric Specification Model specifies global electron density using near-real-time satellite and ground-based data. It became operational in late FY 1996. A second ionospheric model, the Ionospheric Forecast Model (IFM) will be based on a model developed by Utah State University. When completed, IFM will provide an ionospheric forecasting capability; it is currently undergoing validation. Ionospheric model output will be used as input for space track radar correction and HF radio wave propagation programs. Another variant of ionospheric models, the Wide-Band

Model, will provide estimates of ionospheric scintillation severity between two endpoints. The specification accuracy of this model has recently been improved by the inclusion of equatorial and high latitude climatological data.

- The Interplanetary Shock Propagation Model is designed to predict the time of arrival and the dynamic pressure pulse associated with solar flares. This will provide a 1–3 day warning of geomagnetic storms resulting from solar activity.
- The Integrated Space Environmental Model is a coupling model and executive system being developed to integrate the SETT models into a single system sharing input and output data. It will provide a single framework to coordinate and facilitate the execution of all SETT models using scientific expertise and decision-making ability within the program, which will increase consistency of the outputs, optimize run times, and decrease forecaster workload.

On 27 April 1999, AFSPC approved a Strategic Plan for DOD Space Weather Support. This plan reorganizes the space weather support structure over the next few years. The end-state configuration transfers operational responsibility for the space weather strategic center function to the AFWA while AFSPC retains responsibility for providing space weather support to DOD space operations missions. This consolidation of the space weather and terrestrial weather strategic center under AFWA at Offutt AFB, Nebraska will enable AFWA to provide seamless aerospace weather support to DOD forces, reduce USAF infrastructure costs, streamline customer support process, and improve space weather services.

#### **SUPPORTING RESEARCH**

The overarching objective of the Air Force meteorological R&D program is to provide system designers and opera-

tional weather support personnel with the technology tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan. More specific guidance is found in Technical Needs, documented in the associated Weather Development Plan.

With the recent restructuring of the Air Force laboratory system into a single Air Force Research Laboratory, the responsibility for conducting and managing environmental sciences R&D (including meteorology and space weather) resides with AFRL's Battlespace Environment Division located at Hanscom AFB, Massachusetts. Its applied research program in meteorology has been refocused and narrowed to emphasize weather prediction methods, cloud modeling and simulation, weather impact decision aids and optical turbulence for airborne laser applications. AFRL also conducts customer supported R&D for NPOESS, the Defense Modeling and Simulation Office (DMSO), the National Reconnaissance Office (NRO), DOT and NASA.

Weather Prediction Methods. R&D efforts in this area focus on the development of aviation-mission-impact-variable algorithms to be applied operationally at AFWA. Multivariate diagnostic algorithms, applicable to data provided by global and theater-scale numerical weather prediction models, have been developed to infer cloud characteristics (layered and total cloud amount, bases, tops, ceiling), aviation hazards (icing, turbulence, and thunderstorms) and surface conditions (present weather and horizontal visibility). The cloud, icing and turbulence algorithms have been implemented at AFWA where they are being evaluated operationally as part of the Global/Theater Weather Analysis and Prediction System (GTWAPS). The present weather, thunderstorms and horizontal visibility algorithms, transitioned to

AFWA in early FY 1999, are awaiting evaluation testing at AFWA.

Cloud Modeling and Simulation. The Cloud Scene Simulation Model (CSSM) has become the cornerstone for in-house and DMSO-sponsored developments to provide physically and radio-metrically accurate cloud simulations. They provide capabilities needed in the Modeling and Simulation (M&S) community for consistent, physically-based synthetic atmospheres to drive war-gaming, training, system design studies, etc. The AFRL focus this past year has been in areas such as: (1) providing an enhanced cirrus cloud model tuned to aircraft-based cloud water content measurements, (2) completing, in collaboration with the Army Research Laboratory, a radiometric validation study, (3) designing an extension of the CSSM to support campaign-level simulations, and (4) transitioning a cloud/NWP model data fusion approach to the exploitation of National Technical Means data. CSSM has reached a point of maturity where it is routinely used in war-gaming demonstrations and exercises (for the Air Force and Navy) and in the conduct of data impact/sensitivity studies (such as was further done for NPOESS).

Weather Impact Decision Aids. A major focus of the Air Force's investment in meteorology R&D deals with the development, evaluation, and implementation of weather impact decision aids (WIDA) which predict the impact of weather and other environmental factors on the performance of electro-optical (IR, NVG, laser, TV) systems. WIDA products can be used to support mission sensors used in weapon, night-vision, and navigation systems. Four of the five products currently in development will provide unit-level weather impact support for mission execution. The fifth, called Weather Automated Mission Planning Software (WAMPS), incorporates WIDA products described below into

AF command and control systems from the force to the unit-level. The mission execution products are: (1) Infrared (IR) Target-scene Simulation Software (IRTSS), (2) EOTDA extension to cover MWIR (3-5 $\mu$ ) wavelengths in addition to LWIR (8-12 $\mu$ ) systems, (3) Night Vision Goggle (NVG) Operations Weather Software (NOWS), and (4) Target Acquisition Weather Software (TAWS). Collectively, they provide tactical aircraft pilots with scene simulation capabilities to plan EO system missions. They combine global terrain and features, target structure, target IR contrast, EO sensor performance models, data, and meteorological and operational planning data to provide commanders and aircrews complete in-theater visualization tools for environmental situational awareness. Unique Navy and Army requirements continue to be incorporated into these developments.

Atmospheric Optical Turbulence. EO and laser systems are adversely

affected by optical distortions induced by atmospheric turbulence. As the sophistication grows in current and next generation military systems, the requirement for more detailed knowledge of the fine scale (meter or less) atmospheric structure also grows. The Airborne Laser (ABL) program is one such system. Since the meteorological conditions that produce turbulence vary, the performance of such systems vary. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. The measurements are performed by a balloon-borne turbulence sensor that is mated to a standard radiosonde. It has been used in this program since the 1980's. It has produced data and empirical models that are in widespread use and are the basis for ABL system specification. Empirical seasonal models have been developed for the theaters. This year, as part of an international cooperation, aircraft measurements of optical and wind turbulence were made in



Figure 3-DOD-5. Artist's rendering of Airborne Laser.

Australia and Japan. The horizontal measurements by the aircraft augment the vertical profiling by balloons. These data are being used to develop models of vertical and horizontal structure of turbulence in the troposphere and stratosphere, models with dependencies on the meteorological sources of turbulence such as jet streams, fronts, mountains, or thunderstorms. The modeling is closely coupled with work on the generation, propagation, and breakdown of gravity waves. The objective of the program is to develop models that allow the forecasting and prediction of system performance.

#### United States Air Force Reserve Command

The United States Air Force Reserve Command's (AFRC) 53<sup>rd</sup> Weather Reconnaissance Squadron (53 WRS) supports the reconnaissance requirements of several NOAA programs. The 53 WRS was established in 1943 as an Air Force weather reconnais-

sance squadron and remained an active-duty unit until 1990 when the unit was deactivated. In 1993, the 53 WRS name was reestablished when the Air Force Reserve 815th WRS was redesignated the 53<sup>rd</sup> Weather Reconnaissance Squadron, United States Air Force Reserve.

The 53 WRS maintains a fleet of 10 specially instrumented WC-130H aircraft at Keesler AFB, near Biloxi, Mississippi. They provide hurricane and winter storm data to the NHC and NCEP. The aircraft provide high-density flight-level data and dropwindsonde messages in near real-time. The 53 WRS has primary responsibility for operational reconnaissance of tropical cyclones and hurricanes in the Atlantic Ocean, Gulf of Mexico, and Eastern Pacific Ocean. Aircraft from NOAA's Aircraft Operations Center augment the 53 WRS during particularly active storm periods and for reconnaissance in foreign airspace. The 53 WRS also

provides the NCEP with reconnaissance of winter storms affecting the East and West Coasts of the United States. On a limited basis, the unit also supports federal and civilian weather research projects.



Figure 3-DOD-6. Patch of the 53 WRS Hurricane Hunters.

**PROGRAM OVERVIEW**

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations--anywhere in the world, at any time. METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. The focus is predominantly on regions outside of the continental United States. Developing METOC forecasts and determining potential effects on weapons system information requires:

- the collection of data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic phenomena; and
- meteorological information in tactical decision aids and mission planning systems.

Naval METOC must support worldwide naval, joint, and combined operations anytime and anywhere. The focus is predominantly on areas outside of the contiguous 48 states.

The Chief of Naval Operations, through the Oceanographer of the Navy (CNO(N096)), sponsors operational Navy METOC services and related research and development (R&D). The Navy provides meteorological services for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. The Oceanographer of the Navy sponsors programs in four closely related disciplines to provide worldwide, comprehensive, integrated weather and ocean support - meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment (Figure 3-DOD-7).

Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy. The Naval Research Laboratory (NRL) and the Space and Naval

Warfare Systems Command (SPAWARSYSCOM) are the primary activities, in addition to various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-185) is Navy's single program manager for METOC system development and acquisition.

**METEOROLOGICAL SERVICES  
UNITED STATES NAVY**

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCOM). Navy METOC activities are involved in worldwide collection of observations ashore, afloat and through remote sensors, and in the assimilation and processing of these observations on a global basis to support analysis and forecasting throughout the world.

The Fleet Numerical Meteorology and Oceanography Center (FLENUM-METOCEN), in Monterey, California, provides global forecasts and analyses. Environmental data is acquired through links with DOD and NOAA conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCEN is the primary DOD global prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory Detachment, also in Monterey.

NOGAPS provides global atmospheric predictions through twice-daily operations runs. However, in near-shore regions, the small-scale interactions between the atmosphere, underlying ocean, and nearby land make it

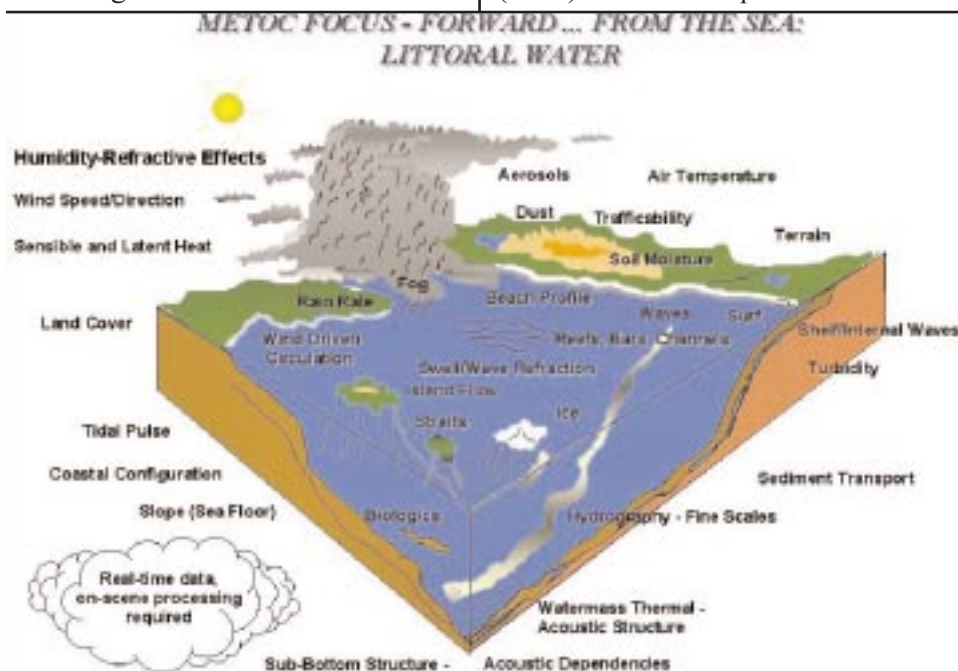


Figure 3-DOD-7. Navy METOC operations encompasses the complex interactions between the atmosphere and oceans.

necessary to analyze and predict the battlespace environment at higher resolution. In addition to the global product suite, FLENUMMETOCEN is uniquely capable of providing high resolution, METOC products on short notice for any location in support of global contingency military and humanitarian operations. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is an operational model featuring nested, non-hydrostatic physics, explicit moisture physics, aerosols, and improved data assimilation. Using NOGAPS lateral boundary conditions, COAMPS provides a high-resolution, re-locatable, meteorological and oceanographic prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Korea, Central America, Western Atlantic, and the Eastern Pacific.

NOGAPS and COAMPS forecast products are distributed via various communications systems either directly to Fleet customers or through the Navy regional METOC centers. The regional METOC centers develop value-added products and services tailored to specific operational requirements. Over the next two years, COMNAVMETOCOM will install computer systems at the regional centers to run COAMPS in theater, allowing them to respond to Fleet commanders' requirements in near real-time. As a complement to numerical forecast products, FLENUMMETOCEN provides atmospheric and oceanographic observations, data extracts, and data for tactical decision aids. Additionally, FLENUMMETOCEN is the designated National Center of Excellence for remotely sensed microwave products under the Air Force/Navy/NOAA Shared Satellite Processing Agreement. The FLENUMMETOCEN web site is [www.fnmoc.navy.mil](http://www.fnmoc.navy.mil).

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with



Figure 3-DOD-8. Navy METOC structure--forward deployed.

oceanography and is the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is the National Center of Excellence for satellite-derived sea-surface temperature (SST) measurements providing the global SST data critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO is a DOD Major Shared Resource Center, enabling creation of the latest R&D models on the most modern scalable supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site is [www.navoceano.navy.mil](http://www.navoceano.navy.mil).

#### Tailored Theater and Regional Support

Theater and regional support are provided to forces both ashore and afloat through six regional METOC services within their broad areas of responsibility (AORs). Aligned with specific

Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs), these centers tailor services to theater requirements, and manage and prioritize dissemination of numerical products from FLENUMMETOCEN and NAVOCEANO (Figure 3-DOD-8). Special products needed to meet requirements of the Joint Force Commanders are also generated by the regional centers. Additionally, the Joint Typhoon Warning Center (JTWC) (operated by the Navy and Air Force) is co-located with the Naval Pacific Meteorology and Oceanography Center in Pearl Harbor, Hawaii.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy (through NAVICECEN), NOAA, and the United States Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civil as well as military activities.

#### Local and Aviation Support

NAVMETOCOM facilities at Whidbey Island, Washington, and at



Figure 3-DOD-9. Naval METOC supports air, surface, and subsurface operations.

Jacksonville and Pensacola, Florida, provide aviation forecaster services as well as Fleet Operating Area (OPAREA) and local forecast and warnings for aircraft, ships, submarines, and naval bases and staffs. Additionally, there are 33 NAVMETOCCOM detachments worldwide. Though primarily situated at Naval Air Stations for aviation safety of flight forecasting, several are located at Naval Stations in support of sea-going units. The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments and facilities within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's National Centers for Environmental Prediction (NCEP). Overseas detachments and facilities use FLENUMMETOCCEN numerical products, in addition to USAF and foreign products.

Two detachments provide specific technical services. The detachment, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as part of the Federal Climate Complex. The detachment, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF Automated Weather Network (AWN).

#### On-Scene Support

The Navy's permanent afloat METOC assets are their OA Divisions, embarked aboard aircraft carriers,

major amphibious ships, and command ships. The OA division's primary objectives are safety of ships and aircraft, optimum tactical support to embarked warfare commanders, and tailored on-scene products and services for the assigned task force/group and Allied units in joint, combined, or coalition military and humanitarian operations.

The primary sources of on-scene Navy METOC support for other forces afloat and those deployed ashore are deployable Mobile Environmental Teams (METs). These teams provide short-term, on-scene services to DOD activities without organic METOC personnel, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. METOC products and services provided by these teams are tailored to each unit's requirements and include tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning.

#### UNITED STATES MARINE CORPS (USMC)

Marine environmental forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, United States Marine Corps (Code ASL-44) is the cognizant office for Marine Corps meteorological and oceanographic support and requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

Garrison aviation weather units at Marine Corps air stations and facilities are manned by USMC personnel and provide direct aviation weather support to host and tenant units (Figure 3-DOD-10). Integral to Marine Corps aviation activities, these weather units provide services to

assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing. The existing 10 MWSS METOC activities are equipped to provide support at a bare-based or expeditionary airfield by deploying the Meteorological Mobile Facility (METMF). Additionally, Meteorological Support Teams (MSTs) from the ACE MWSSs can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

#### MAJOR METOC SYSTEMS

The capability to provide near real-time global, regional, and local METOC services to the Navy and Marine Corps team requires a robust and evolving set of leading edge technology tools. These tools are embodied in the following systems:

Primary Oceanographic Prediction System (POPS). The POPS program was initiated to provide the computational capability necessary to run massive oceanographic and atmospheric models at global, theater, and tactical scales. Cray C-90s at FLENUMMETOCCEN and NAVOCEANO were



Figure 3-DOD-10. Harrier Jump-jet--successful Naval operations rely on accurate environmental forecasts.

installed as part of the Navy's and federal government's emphasis on high performance computing. POPS at NAVOCEANO is a DOD Major Shared Resource Center with as much as 85 percent of the computer time on the C-90 devoted to supporting DOD R&D efforts which can transition to operational use. FLENUMMETOC-CEN uses POPS as the numerical engine in its role as the primary DOD Numerical Weather Prediction Center.

Tactical Environmental Support System (TESS). The Navy is presently undergoing migration towards a modular, interoperable suite of systems to ingest, process, fuse, display, and disseminate METOC data. The program consists of five seamless versions known as the Naval Integrated Tactical Environmental Subsystem (NITES) versions I-V. NITES systems will be fielded in FY 2000 through FY 2004. The five NITES versions are:

- NITES I. Provides Navy decision-makers on major combatant ships with METOC assessments and forecasts, and integrates data with sensor and weapon platform parameters for system performance assessments. Theater METOC centers use NITES I to provide value-added products to fleet units, and the numerical prediction guidance generated by FLENUMMETOC-CEN.
- NITES II. Makes METOC data and products available to Navy and Marine Corps activities afloat and ashore via the Global Command and Control System-Maritime (GCCS-M). TESS data and products are used to feed tactical decision aids resident within GCCS-M. NITES II is the basis for the Joint METOC Segment of the new Global Command and Control System (GCCS) V3.0.
- NITES III. An unclassified forecast, briefing, and display system tailored to Naval METOC shore activities in support of aviation operations.

- NITES IV. A portable system tailored to METOC requirements. Fielding of NITES IV is expected to commence in FY 2004.
- NITES V. A forecast, briefing, and display system for foreign military sales to ensure interoperability with our allies. It is a follow-on to the Allied Environmental Support System (AESS) and will incorporate capabilities used in the other NITES variants.

Meteorological Data Receiver-Recorder (AN/SMQ-11). The principal Navy system to acquire environmental data directly from satellites. There are different equipment configurations for ships and shore sites; through their interface with TESS variants, they provide remotely sensed information to the operator.

Automated Surface Observing System (ASOS). ASOS supports aviation and local area observing requirements at Navy and Marine Corps stations worldwide, leveraging development efforts of the National Weather Service (NWS). ASOS assists meteorological technicians assimilate field meteorological parameters and facilitates efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Supplemental Weather Radars. The Navy has procured supplemental weather radars to provide Doppler weather radar coverage at selected Navy and USMC sites, mostly overseas, outside of NEXRAD coverage. This system replaced the obsolete AN/FPS-106 weather radars.

Meteorological Mobile Facility Replacement (METMF(R)). The METMF(R) is a transportable system that houses meteorological support equipment for the Marine Air Ground Task Force (MAGTF). This 8 x 8 x 20 foot van provides a fully functioning weather office designed to support for Marine Corps expeditionary airfield operations for 30 days without resup-

ply. It includes sub-systems for data collection (local, remote and upper air sensors), data processing, satellite data ingest and display, Doppler radar, communications, briefing support, and support for remote forces. The METMF(R) is interoperable with the Marine Corps C4I systems and METOC systems of the other services via the Global Command and Control System (GCCS).

#### Operational Products and Services

Optimum Track Ship Routing (OTSR), and Optimum Path Aircraft Routing System (OPARS) are advisory services for fleet units. They are based on NOGAPS and COAMPS data, tailored to the customer, and provide guidance to the forecaster for the safe operation and cost-effective routing of DOD ships and aircraft, as they have for nearly 30 years. OTSR and OPARS save the warfighter approximately \$57M per year in reduced fuel consumption.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package developed in 1982 to make FLENUMMETOC-CEN numerical products available to front line DOD users. All standard meteorological and oceanographic fields, synoptic observations, and basic DMSP satellite imagery is also available. NODDS is available to non-DOD federal agencies and others in the civilian community through an agreement between Navy and NOAA.

The Joint METOC Viewer (JMV) is a new capability that is integrated into NITES and will eventually replace NODDS. Building on the availability of the Internet and the successful user interface of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing, and annotating METOC information. Authorized DOD and government users with Internet access now have a simple, cost-efficient way to display weather and ocean information on various computer platforms and operating systems. JMV is operational at several hundred

DOD sites, including ships.

Since 1983, the Naval Regional Meteorology and Oceanography Center, in Norfolk, Virginia has provided long-range forecasts in support of Energy Conservation efforts at Naval shore installations in the continental United States. The services are primarily in the form of extended-range (10-day) temperature forecasts provided to energy managers to assist in optimizing power plant operations. Monthly temperature/degree day outlooks and long-lead (12 month) seasonal and precipitation forecasts are also issued to assist in strategic planning of fuel purchasing and resource allocation. Documented savings from the Energy Conservation Forecast Program exceed \$62 million, with the majority of savings resulting from power plant steam/air conditioning on/off recommendations and energy resource/fuel allocations based on long-lead forecast products. Customers include 128 Navy and Marine Corps facilities and commands.

### SUPPORTING RESEARCH

The Navy administers a diverse R&D program, ranging from software development to sensor engineering, and processing, display, and distribution devices. Application of R&D activities of other services and federal agencies is always considered, and use of existing government and commercial off-the-shelf items is emphasized.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific



Figure 3-DOD-11. The National Ice Center produces tailored ice analysis and forecasts.

research, through additional development, into operational meteorological and oceanographic models is key to a successful numerical prediction program. This on-going process includes work at universities and the Naval Research Laboratory's Marine Meteorological Division to keep the NOGAPS and COAMPS at the leading edge of technology. Development is also underway to improve data assimilation, quality control, and management techniques to support these models. A major numerical weather prediction thrust is underway to develop a shipboard tactical atmospheric forecast capability to assimilate locally acquired data in real-time and deliver high resolution (5 km), limited area (100s of km), short range (12-24 hr) atmospheric predictions in tactical timeframes.

The Navy R&D program in remote sensing develops techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are exploited to the greatest extent possible and plans are in place to incorporate new capabilities when introduced. Because many satellite processing algorithms are designed for use with tactical systems, expert or rule-based processes are used where possible to reduce human-intensive interpretation.

ONR and SPAWARSSCOM continue to explore techniques for assimilating environmental data through non-traditional sensors. One such effort is investigating the AEGIS Weapon System's AN/SPY-1 radar and developing the ability to produce NEXRAD-like radar information from ships at sea.

#### Interagency Cooperation

Navy and Air Force have been cooperating in DOD weather support for many years and these efforts have led to successes, such as the DMSP and JTWC. Recently, the two service have reinvigorated efforts to increase efficiencies in their METOC programs through greater cooperation. The



Figure 3-DOD-12. Weather conditions over the ocean can change rapidly and affect NAVAL operations significantly.

NAVAF-21 Charter, signed in June 1999 by the Oceanographer of the Navy and the Air Force Director of Weather, expands on the 1992 NAVAf Agreement for long-term cooperation in DOD operational METOC efforts. NAVAf-21 implements mechanisms to formalize information exchange and cooperation, focus limited resources, and prioritize issues to most efficiently meet long-term DOD METOC requirements, and establish an enduring methodology for documenting and periodically reviewing decisions on areas of mutual interest.

To maximize efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) was signed in 1993. Both agencies continue to identify new areas of cooperation and review existing agreements for conversion into annexes to this MOA. Specific areas include:

- Cooperative efforts in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCEN and the NCEP.
- Navy/NOAA/Coast Guard operation of the National Ice Center (Figure 3-DOD-11).
- Air Force Weather Agency (AFWA)/Navy/NOAA agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.

<ul style="list-style-type: none"> <li>• Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).</li> </ul> <p>MOAs also exist between the Department of Commerce, Department of Transportation, and the Department of Defense concerning procurement and operation of NEXRAD. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).</p> <p><u>Natural Disaster Mitigation</u></p> <p>Navy METOC plays a vital role in reducing the impact of natural disasters to units both ashore and afloat. Severe weather warnings are issued at Naval facilities by the local NAVMETOC-COM activity when conditions warrant. For ships operating at sea without METOC personnel embarked, tailored enroute weather forecast messages (WEAX) and high winds and seas warnings provide commanding offi-</p>	<p>cers with advance notice of heavy weather; Optimum Track Ship Routing (OTSR) forecasters monitor ship movements and provide heavy weather avoidance recommendations.</p> <p>Tropical cyclones and even severe winter storms provide even greater challenges, as ships cannot generally "ride out" storms in-port without sustaining damage. Similarly, once they get underway (or "sortie"), ships must steer well-clear of the highest winds and seas to avoid personnel injuries and damage and ensure their stability limits are not exceeded. Even storms of little consequence to the general public - those that remain well out at sea - are still of great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3- to 5-days in advance of potentially dangerous weather. Sortie decisions are extraordinarily difficult to make because of their high cost and impact on personnel and operations. In making these decisions, Fleet commanders must strike a</p>	 <p>Figure 3-DOD-13. JTWC forecasts tropical cyclones in the Pacific and Indian Oceans.</p> <p>balance between the risk of staying in-port versus the cost and potential for damage at sea.</p> <p>Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS, the forecasts are closely coordinated with the NWS. Overseas, local warnings and forecasts are based on guidance provided by the JTWC.</p>
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## UNITED STATES ARMY

### ARMY OPERATIONAL SUPPORT Overview of Operational Equipment and Support Missions

United States Army weather support is a mix of Army and Air Force (AF) personnel and equipment under Law and according to Army-Air Force agreement. Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the United States Army, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army providing weather support. The United States Army provides direct weather support to two Army missions: upper air observations for field artillery fire

support, and limited surface weather observations to support Army weapon systems forward of division tactical operations centers (Figure 3-DOD-14). AF Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. United States Army Forces Command (FORSCOM), United States Army Europe (USAREUR), United States Army Pacific (USARPAC), United States Army, South (USARSO), United States Army Special Operations Command (USASOC), Eighth United States Army (EUSA), and United States Army Training and Doctrine Command (TRADOC) have AF

Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime, training and activation the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the reserve component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army Weather Teams (WETMs). The ANG acts like an AF MAJCOM in providing support to the Army RC.

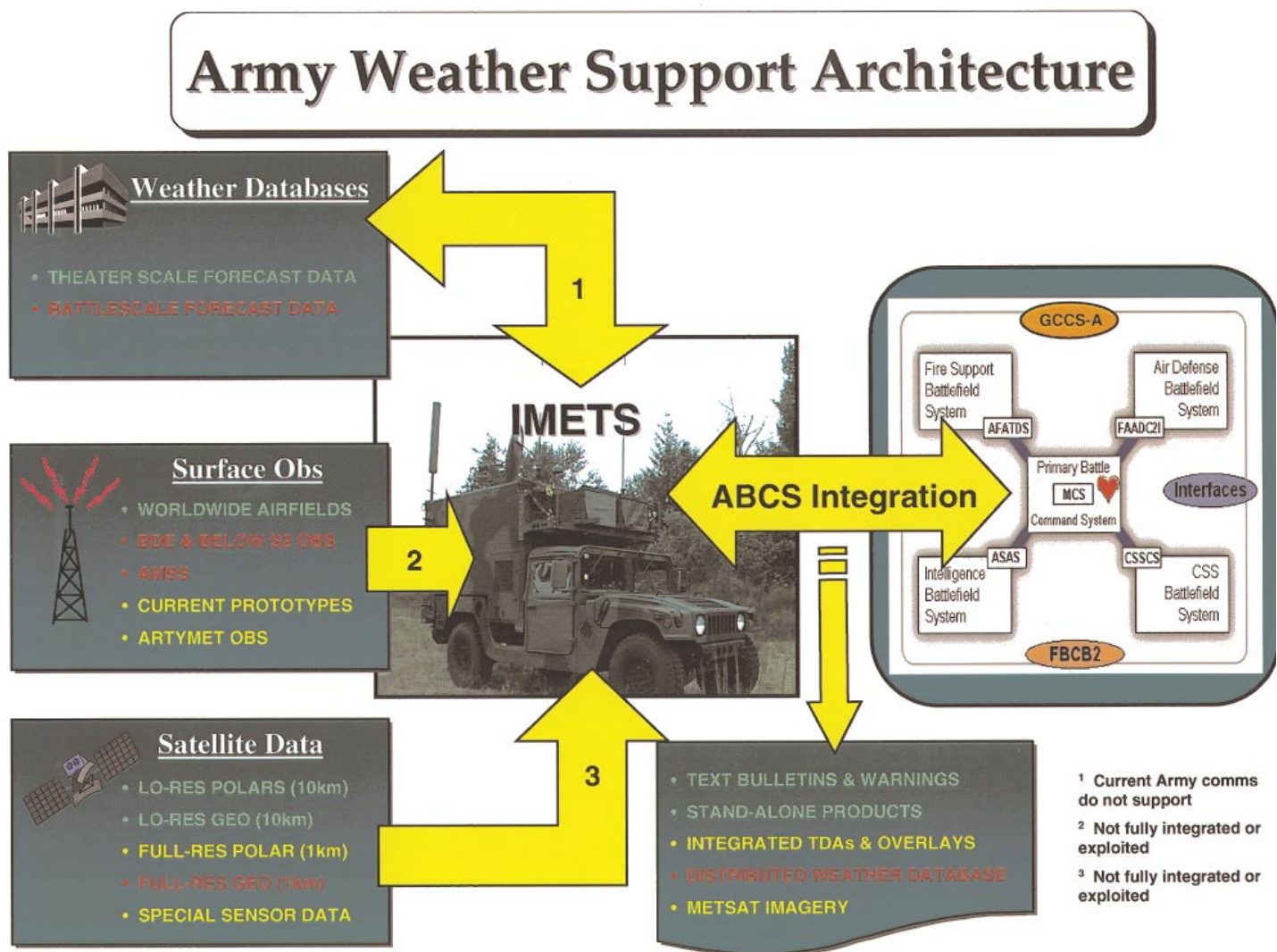


Figure 3-DOD-14. Army Weather Support Architecture.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Test and Evaluation Command (TECOM) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (SMDC) contractors. TECOM operational support is described under Army Materiel Command in the RDTE section. SMDC provides weather support to Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to AF WETMs for tactical operations. The Integrated Meteorological System (IMETS) is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to field artillery meteorol-

ogy programs. Previously issued Block I IMETS have been upgraded to ensure Y2K compliance. Block II IMETS currently being issued are Y2K compliant. IMETS fielding continues in FY 2000.

ARTYMET crews are assigned to artillery units at division level, to field artillery brigades, and to separate brigades with a direct support artillery battalion. Army soldiers regularly take tactical upper air observations to support field artillery units during tactical training exercises, at permanent Army artillery ranges, or during the full range of combat missions. ARTYMET crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET crews in the active component (AC) and some RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations (Figure 3-DOD-15). It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides

upper air data to the field artillery tactical data system for use in adjusting artillery fire, to AF WETMs, and to the chemical officer for use in smoke and in nuclear, biological and chemical (NBC) defense operations. (The CECOM section provides a complete description of MMS). The Meteorological Data System (MDS), AN/TMQ-31, replaced by the MMS, has been reissued to the Army National Guard (ARNG) and will be used as long as still supportable. The rest of the ARNG units will be upgraded to the MMS and future Profiler systems, as they become available. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirement documents and is the combat and training developer for meteorological equipment used for field artillery support.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. When directed by the Intelligence Officer (S2), Intelligence personnel in the forward combat areas take these observations.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office.

Army Operational Support provided by the Air Force

Under AR 115-10/AFJI 15-157, the AF is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison AC/RC support requirements. Army support manpower requirements



Figure 3-DOD-15. AN/TMQ/41 MMS.

are sourced from AF active, reserve, and ANG weather units. While direct support of the field artillery remains an Army responsibility and is supported by Army ARTYMET teams, AF WETMs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiments to provide direct, on site weather support. AF weather squadrons and flights provide garrison and tactical weather warning, observing, forecasting, special support, and SWO services to combat, combat support, and combat service support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. The AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army airfield weather stations. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army IMETS is fielded for these purposes and is operated by AF WETMs. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to AF WETMs through an Army Table of Organizations and Equipment (TOE).

#### United States Army Space and Missile Defense Command (USASMDC)

Army Space Command (ARSPACE), a subcommand of USASMDC, provid-

ed Army Space Support Teams (ARSST) to deploying Army units. One element of this support has been a high-resolution weather satellite receiver, which can be readily transported, and directly acquires and processes the full telemetry stream of civilian and military weather satellites. Imagery and data are used by the SWO in preparation of tailored products and forecasts for use on the battlefield. This equipment is used in contingencies and training exercises, and provides an interim capability pending delivery of IMETS, Block II and associated AF weather satellite equipment.

The Army Space Command's ARSST stood down their weather capability in FY 1998. The ARSST weather satellite receiver assets will transfer to the SMDBL in FY 1999.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASMDC, located on White Sands Missile Range, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser system test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HELSTF activities by providing atmospheric propagation and meteorological measurements, planning, and analysis as required. These capabilities also support the safe storage, handling and use of the toxic laser fuels.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support to the test facilities at the Kwajalein Missile Range (KMR). The KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and

the preparation of daily aviation, marine and special weather observations for the range.

#### Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) operates a land-based network of about 7,400 gages of which 1,900 are limited observing meteorological sites. The remainder is hydrologic in nature. The meteorological portion measures precipitation and other data in the United States to provide information for regulating COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 900 of these sites. Similarly, COE transfers funds to the United States Geological Survey to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Data from many of these sites are automatically telemetered using satellite, microwave, landlines, radio, etc. to provide for real-time use of the data. Although the COE finances the network, data are made available to all other federal agencies.

#### Eighth US Army Support

Eighth United States Army (EUSA) requires, and uses, Army resources to conduct two major meteorological services in direct support of Army operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observations to support all tactical units and operations.

Two artillery meteorological (ARTYMET) crews with the Second Infantry Division AN/TMQ-31 Meteorological Data Systems are assigned to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect routine (usually daily) upper air observations for training; these observations are typically fed into the global weather database.

Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers during contingencies or exercises and, in turn, are disseminated to and through AF WETMs teams supporting Army air, ground, or special operations.

AF weather personnel assigned to the 607th Weather Squadron (607 WS) provide fixed and tactical weather support to EUSA units and installations. 607 WS provides garrison and tactical weather warning, observing, forecast, special support, and SWO services during contingency, exercise, or armistice operations. 607 WS units provide direct, on-site support at eight EUSA installations and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. 607 WS provides 97 trained weather personnel and required fixed and tactical weather sensing, data processing, and communications equipment. EUSA provides supporting AF units needed tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment, and operating funds (for expendables, maintenance, etc.).

#### Training and Doctrine Command (TRADOC) Programs

HQ TRADOC is responsible for development and management of training programs, writing Army and Joint weather support doctrine (concepts and field manuals), and establishing the weather requirements documents for Army tactical weather support equipment. Headquarters, TRADOC is the approval authority for Army-AF weather doctrine, Army weather hardware requirements, and weather support policy.

Key mission area for the next few years will be to coordinate Army weather support requirements during AFW Reengineering and Army Task

Force XXI Advanced Army Warfighting Experiments (AWEs). Deployed weather support will improve significantly with the digitizing of these experimental Army units. Customized battlefield weather "visualizations" transmitted via IMETS will take the place of the stand-up weather briefings of the past. The AWEs will result in the development of new tactics, techniques, and procedures for the exploitation of weather during military operations. Identified software enhancements will transition to the appropriate materiel developer for further integration. Finally, these experiments provide an opportunity to educate Army leaders and their staffs on the effects of weather on the battlefields of the future. The Capstone event will be the Joint Contingency Force War game in summer 2000.

TRADOC schools submit requirements for weather support to HQ TRADOC for approval. Upon concurrence, HQ TRADOC normally states requirements for AF support to HQ, Air Combat Command for implementation. Requirements for Army provided communications or tactical equipment are submitted through ODC-SOPS to prioritize and program resources.

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the proponent for Army tactical weather support. USAIC&FH works with the Intelligence Center, Army Research Laboratory, and the AFWA to identify and overcome deficiencies in Army weather support. In addition, USAIC&FH is the proponent for *"Owning the Weather"*, a concept for exploiting weather as a force multiplier on the battlefield. The USAIC&FH weather division employs an AF SWO, a senior Noncommissioned Officer, a senior meteorologist from Army Research Laboratory (ARL), and a civilian intelligence analyst. The division writes weather support concepts, requirements and doctrine. They

develop and provide weather support training to Army Intelligence and AFW personnel supporting the Army. During 1999 and 2000, they will be working on the Joint Integrated Weather Effects Decision Aid (IWEDA) program, and Joint Target Acquisition Weather Software for Electro-Optic weapon support.

The Staff Weather Officer at the United States Army Combined Arms Center facilitates modifications to the Tables of Organization and Equipment for Army CWTs, and through the TRADOC System Manager for Army Battle Command System and Battle Command Battle Laboratory-Leavenworth, provides environmental data for the Command, Control, Communications, Computer and Information (C4I) network.

The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the Army. Artillery meteorological crews, active and reserve, currently use the AN/TMQ-50 to measure surface weather parameters, and the AN/TMQ-41 Meteorological Measuring Set (MMS) to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to AF CWTs for weather forecasting; and to the Chemical Officer for obscurant deployment and NBC defense operations.

The Engineer School (USAES), Fort Leonard Wood, Missouri coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying, and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center.

In 1999, the Army Military Police and Chemical Schools will also move to Ft Leonard Wood. Neither currently employ staff meteorologists.

The Aviation Center incorporates weather instruction and procedures into training programs in their mission areas. In addition to aviation training at Cairns AAF, the center has requirements for weather observations and AF forecast support at Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay all types of AF-provided weather information to numerous Army remote training sites. In FY 1999, the Aviation Center installed 5 new ASOS.

#### United States Army Special Operations Command (USASOC)

The intent of weather support to USASOC is to provide planning, command decision, and mission execution weather forecasts and observations to improve efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited meteorological observation services in direct support of Army operations using tactical weather kits to collect limited weather observations in data sparse, permissive and non-permissive environments. Observations are typically collected by Army special operations forces at the team level and passed to operating bases for use by Army commanders and staff, as well as AF Special Operations Weather Team (SOWT) personnel. AF weather personnel supporting USASOC are assigned to the 10th Combat Weather Squadron (CWS). The 10 CWS provides garrison and tactical weather support to USASOC units including the 75th Ranger Regiment and three subordinate battalions, the 160th Special Operations Aviation Regiment and three subordinate battalions, and five Special Forces Groups and their subordinate battalions. Weather support encompasses climatological infor-

mation, mission forecasts, command decision forecasts, aviation forecasts and observations, drop zone forecasts and observations, special weather reconnaissance, and the establishment of indigenous weather observation networks. The 10 CWS also provides staff support to USASOC, the United States Special Forces Command, and the United States Army John F. Kennedy Special Warfare Center and School. USASOC provides supporting AF units with required tactical vehicles, communications equipment, tactical equipment, and operating funds (for expendables, maintenance, etc.).

#### **WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)**

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations. The Space and Missile Defense Battle Laboratory (SMDL) supports research related to space-based weather products.

#### Corps of Engineers (COE)

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in AR 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by three COE laboratories: Topographic Engineering Center (TEC), Cold Regions Research and Engineering Laboratory (CRREL), and the Waterways Experiment Station (WES). TDAs interpret the impact of weather

and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. Critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology Demonstration results are being transitioned to terrain and weather systems such as the IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS), and Battle Command Decision Support System.

The COE Topographic Engineering Center (TEC), Fort Belvoir, Virginia provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This includes the development and integration of environmental effects databases and models that are relevant to military plans, operations and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules that are designed to be exploited in the synthetic environment arena and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC

also reviews all emerging materiel systems for environmental effects.

Under the military portion of its civil and military support mission, the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, provides weather support to Army weapon systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL is responsible for modeling in the areas of Cold Regions Surface-Air Boundary Process, Winter Scene Dynamics, and Spatially Distributed Prediction Over Winter Terrain. CRREL develops databases and models predicting infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Other specific programs include weather effects on environmental research for military training lands, aircraft including helicopter airborne and ground anti-icing and deicing, remote sensing including satellite weather input for predicting snow coverage and snow melt runoff in Areas of Operations (AO), special geographic winter weather interpretation/reporting for commanders in various AOs, and special weather effects in winter conditions that directly affect operations.

#### Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather research and development responsibilities.

TECOM is a subcommand of AMC providing operational support to 10

ranges and test sites with Meteorological (MET) Teams. Under responsibilities established in AR 115-10/AFJ 15-157, the TECOM MET Teams provide weather support and atmospheric characterization to Army RDTE. MET Teams provide atmospheric data collection, analysis, consultation, warning, and forecast services for Army and other DOD RDTE. MET Team FY 1999 funding has been level for 3 years following several years of decline, using a combination of both programmed funds and users funding. This enables TECOM to continue basic meteorological support at Army RDTE ranges and sites, but meteorological instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. TECOM MET Atmospheric Sciences Branch has a 5-year effort with the National Center for Atmospheric Research (NCAR) to greatly improve "range scale" (mesoscale to microscale), forecasting and analysis technology. Using the MM5 model as a base, this Four Dimensional Weather (4DWX) System will present both real-time and forecast three dimensional pictures of the MET and other atmospheric characterization parameters in, around, and up to 50K feet over the Army's test ranges. The 4DWX system will provide improved test scheduling, more accurate placement of sensors during a test, more cost-effective measurements, data sets for virtual testing, and instantaneous forensic analysis (instant replay) of the conditions that occurred during the test. In addition to RDTE support, the Dugway Meteorology & Obscurants Division's Modeling and Assessment Branch provides the following specialized services: (1) atmospheric model validation, to include algorithm evaluation and the generation of validation data sets; (2) chemical/biological threat analysis, detection, and decontamination tests

and studies through the Joint Contact Point (Project DO49); and (3) prototype development of virtual proving ground meteorological support. Division members also serve on various national and international committees addressing issues related to meteorological measurements and atmospheric dispersion modeling.

The ARL Battlefield Environment (BE) Division is the lead DOD agency for research and development in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to provide the technology and tools (1) for the soldier to exploit weather on the battlefield, (2) for the commander to avoid exposing the soldier to environmental hazards, and (3) for the materiel developer to minimize system weather impacts, supplying atmospheric effects information. The joint Army/AF "Own The Weather" initiative will provide knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute to the Army's decisive advantage over its opponents. Within the DOD, BE is the lead agency for multi-service R&D programs in transport and dispersion modeling, boundary layer meteorology over land, and mobile atmospheric profiling. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects. The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the AF, Navy, or civilian community, and over data-sparse geographic regions. While the AF provides the Army with its basic tactical weather support, the Army provides technology to support such service-unique requirements, and Army systems, as well as distributing this weather intelligence information to the Army Command and control systems on the battlefield.

The Army has begun an active re-programming to respond to the new AFW Reengineering initiatives, and will work to ensure the ongoing success of the Army weather intelligence technology. BE continues to develop and provide the software tools for the Army's IMETS, and works with the AFWA and Combat Weather Center to make IMETS an integral part of the total battlefield weather support mission.

The BE Division within the ARL Information Science and Technology Directorate, consists of four Branches, two each at the ARL primary site at Adelphi, Maryland, and the White Sand Missile Range, New Mexico. The Adelphi, Maryland, Branches specialize in a basic research program, while the WSMR Branches support an applied research development program for Army tactical applications. BE opened an experimental site at Blossom Point, Maryland, in mid-1998, in a complex littoral region on the north shore of the Potomac River, and will conduct field experiments in electro-optic and acoustic propagation, as well as test weather modeling tools.

At the Adelphi Laboratory Center (ALC) in Maryland, the two branches are the Atmospheric Acoustics and Electro-Optics (A&EO) Propagation Branch and the Boundary Layer Meteorology and Aerosol Research Branch (BLM&AR). The A&EO Branch provides basic research in the modeling and simulation of environmental effects on acoustic and electro-optics propagation, and laboratory and field experimental research into environmental effects on acoustic and electro-optic propagation and the mitigation of those effects. The BLM&AR Branch conducts a research program in the micro-meteorological processes and structure of the atmospheric boundary layer. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes and on optical methods of detection of aerosols (primarily chemical-biological agents) and the modeling of

their transport and dispersion in the tactical environment.

The Weather Exploitation Branch, Battlefield Environment Division's R&D efforts involve several areas. They address tactical weather data assimilation and distribution, to include exploitation of commercial and military satellite technology to move meteorological data to the battlefield Tactical Operations Centers and between echelons. They generate gridded meteorological databases to support C4I systems, mission planning and rehearsal, and integrate weather forecast analysis tools to identify the location and timing of hazardous and significant weather at small scales in the boundary layer. They develop rule-based tactical decision aids for impacts of weather on military systems, platforms and operations. And, they integrate physics based weather effects models and meteorological satellite analysis algorithms with weather data visualization tools for improved mission planning and situation awareness. As part of the tactical weather product development, the branch also performs: (1) configuration management and validation of new products; (2) improvements through end-user feedback from Advanced Warfighting Experiments, TRADOC Concept Experimentation Programs, and integration at the Army's Central Technical Support Facility at Ft. Hood; and (3) delivery of software for integration into IMETS. The IMETS integration includes tactical weather overlays, databases of dynamic gridded weather parameters, weather effects decision aids, and weather data visualization tools, all of which can be executed in the field using Common Hardware/Software and Common Operating Environments.

BE develops the weather application software for IMETS that is part of the Army's effort to digitize the battlefield and will provide weather capabilities in the Army's First Digitized Division (FDD) in FY 2000. From FY 1997 to

the present, BE has successfully used the Army's Task Force XXI Advanced Warfighting Experiments (AWE's) to evaluate and improve its delivered IMETS Block I and Block II software. In FY 1999 and FY 2000 the BE/IMETS tactical weather applications are being upgraded and delivered for integration to the other C4I tactical systems operating under the Army Battle Command System, version 5.0 (ABCS 5.0). These IMETS applications incorporate significant changes in the sharing of data between battlefield functional areas by exploiting client/server relationships and the IMETS gridded meteorological database. The weather overlays are converted to use the Joint Mapping Tool Kit (JMTK) software for map overlays. The initial integration of AFW Reengineering includes passing meteorological data and products from AF central hub sites to the Army battlefield TOC's using WMO data standards, such as GRIB and BUFR. The joint rules and critical values for the BE-developed Integrated Weather Effects Decision Aid (IWEDA) are being assembled jointly across the services to provide a common rule-base for weather impact decision aids.

The Army Research Office (ARO), Research Triangle Park, North Carolina manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamics and kinematics processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical

basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of special funding are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (EPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also, basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. At the Army Research Office, funding for basic research remains relatively static. Increased funding will come if special program initiatives or requests are approved. The primary focus will be on analysis and understanding of data taken in a recent field study of the stable boundary layer.

The CECOM Intelligence and Electronic Warfare (IEW) Directorate (Dir), Fort Monmouth, New Jersey assists the CECOM level II manager and other internal organizations in developing and fielding weather support systems; and helps the program manager, Intelligence Fusion with technical management of weather programs. Current programs supported are the Meteorological Measuring Set (MMS), the Profiler, and the IMETS. A brief description of each of these programs shows IEW Dir's involvement and supplements earlier discussions under the other MACOMs.

#### Meteorological Measuring Set (MMS), AN/TMQ-41.

The National Guard is planning to purchase 40 MMS's beginning in FY 1999 and continuing through FY 2002. This purchase will be the final Army buy of the MMS. The Intelligence and Information Warfare Directorate (I2WD) is providing technical support to the system manager (CECOM Logistics and Readiness Center) for this effort. All active Army units have been fielded. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). The contractor, Environmental Technologies Group (ETG), has built 42 systems for the Army and National Guard, 21 systems for the Marines, and 11 systems for Foreign Military Sales (10 for Canada, 1 for Bahrain). Upgrades to the MMS are currently underway. The Global Positioning System (GPS) upgrade will act as a Navigational Aid (NAVAID) to determine radiosonde

position. GPS will replace the current NAVAID chains (LORAN-C and VLF/OMEGA) when they are abandoned. The GPS processor will fit inside of the meteorological processor. Another upgrade is the Semi-Automatic Meteorological Station (SMS), AN/TMQ-50 (Figure 3-DOD-16). The SMS will collect atmospheric pressure, temperature, humidity, wind speed, and wind direction at the surface and automatically transmit this data to the meteorological processor. The GPS and SMS upgrades are being fielded to all active Army and National Guard MMS in FY 1999.

#### The Meteorological Measuring Set-Profiler (MMS-P) System.

The Meteorological Measurement Set-Profiler (MMS-P) is a major product improvement to the MMS. It will provide current meteorological systems with new capabilities to determine target area MET. A suite of remote sensing instruments combined with a meteorological satellite receiver will eventually replace the current rawinsonde system with an onboard mesoscale mode for analyses and fore-



Figure 3-DOD-16. AN/TMQ-50 Semi-automatic Meteorological Station (SMS)

casts, which will reduce the time staleness of the atmospheric data. These sensors will be capable of measuring the atmosphere on an almost continual basis. The primary remote measurement instruments are a wind profiling radar and a passive microwave radiometer for temperature profiles. A new Semi-Automated Meteorological Station (SMS) now in the Army inventory, provides surface measurements. Atmospheric profiles from the ground based systems are combined with the soundings generated from meteorological satellite data to form merged soundings that can extend from the surface to about 30-km. A mesoscale model with interface software will use the local profiles and other data (e.g. NOGAPS) to generate a 3-D analysis over an area of up to 500 x 500 km, and forecasts for several hours. The entire system fits in a shelter carried by a High Mobility Multi-purpose Wheeled Vehicle (HMMWV) plus a High Mobility Trailer (HMT). A separate vehicle tows a tactical quiet generator. Preliminary comparisons with rawinsonde data for the first 5 or 6-km upward from the surface suggest that the MMS-P profiles are at least as good as concurrent rawinsonde soundings. Planned upgrades include neural network methods to derive temperature and wind soundings from satellite data, an upgraded mesoscale model and improved instrumentation. The instrumentation upgrades include a moisture profiling capability in the radiometer, and an electronically steered radar for very rapid set up times and potentially the ability to acquire soundings on the move. ARL performed the initial research on this project. CECOM is providing technical assistance to PM, NV/RSTA on the program. The current plan is to procure two Engineering and Manufacturing Development (EMD) models in FY 2000, with a production decision scheduled for FY 2002.

#### The Integrated Meteorological System (IMETS) AN/TMQ-40A

IMETS is a tactical meteorological collection, analysis, forecasting, dis-

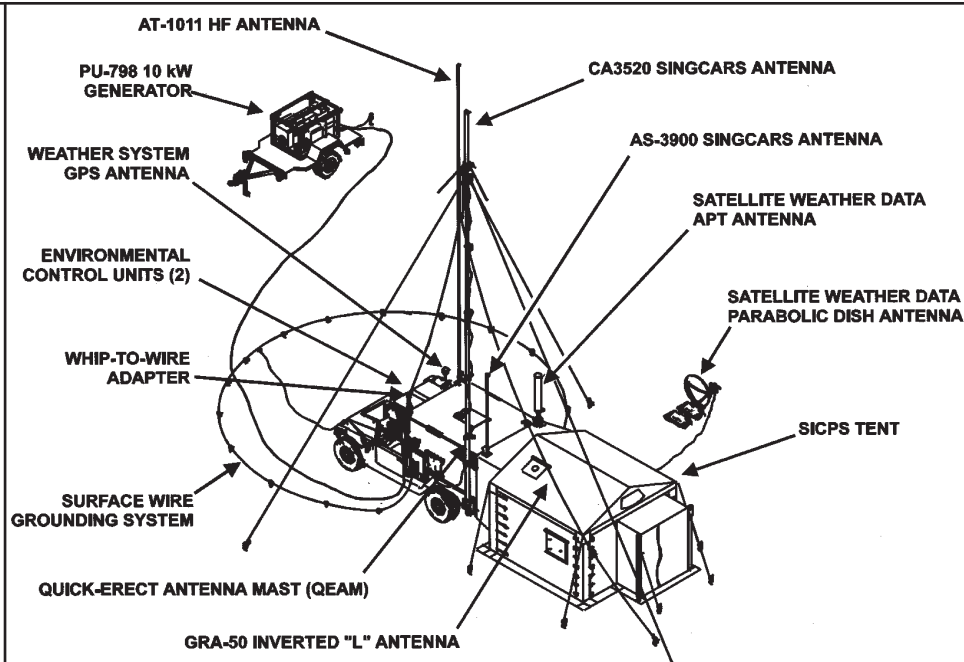


Figure 3-DOD-17. AN/TMQ-40A Meteorological System, Automatic.

play and dissemination system. Data can be collected from sources such as military and civilian forecast agencies, satellite imagery, upper air Army artillery teams, AF weather observation teams, etc. The IMETS is capable of merging two or more tactical data displays to form composite displays over various map and digital terrain backgrounds; combining satellite imagery with surface observations; and display forecast rain and cloud imagery movement. Data can be disseminated over landlines, area communications and HF radio. FY 1999 efforts will focus completing fielding of Y2K compliant and Single Processor Configuration (SPC)/Block II systems. FY 1999 efforts will also include developing support documentation to achieve a Milestone III decision for the IMETS Operational Requirements Document (ORD) expected to be approved in August 1999. The CECOM Research and Development Engineering Center (RDEC) I2WD supports the CECOM level II manager for the MMS, PM, NV/RSTA for the Profiler, and PD IMETS/PM Intel Fusion with technical management of the programs. I2WD provides no operational support.

I2WD provides technical engineering support using customer funding. No I2WD mission funds are used. CECOM Logistics and Readiness Center is buying MMS's for the National Guard. I2WD will provide technical support. The National Guard is providing the funding for this effort. Medical Research and Materiel Command

The United States Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude, and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational

envelope for both training and operational scenarios.

Current efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources that are relevant to dismounted infantry operations. In support of the Army Ranger training facility at Eglin Air Force Base (AFB), Florida, Medical Research and Materiel Command and USARIEM are participating in the development of an automated thermal injury risk assessment system. The MERCURY-Ranger test bed system is a partnership effort with the Army Research Laboratory's Battlefield Environment Directorate (ARL/BED), the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM), and the US Air Force 46th Weather Squadron at Eglin AFB. The test bed system ingests hourly data from several local surface weather stations and automatically spreads the data across a 100 by 100 km region using objective and heuristic interpolation methods. The resulting high resolution (1-km) gridded weather data fields are then used as inputs to the thermal strain prediction models for heat stress and cold air exposure. Results are displayed as color coded map overlays of thermal injury risk categories or tolerance times. A prototype cold water partial immersion model has been developed and implemented in cooperation with DCIEM. That model uses real-time water temperature and depth measurements along with standard weather parameters at river locations to predict safe exposure times in cold water river fording scenarios. The highly automated test bed system is intended to provide a platform for evaluating methods needed to translate real-time weather information into robust assessments of soldier system health risks and performance limitations.

#### Space and Missile Defense Battle Laboratory (SMDBL)

The Space and Missile Defense Battle Laboratory (SMDBL), a component of USASMDC, conducts experimentation, testing, and integration activities for the purpose of providing space-based weather products to Army and joint command and control system users. In January 1998, the Army's Battlefield Visualization Integrated Concept Team (BV-ICT) determined weather products for battle command was an area requiring immediate attention. With the Battle Command Battle Laboratory – Leavenworth as executive agent, a group was formed to plan and execute a battle Laboratory experiment in accordance with TRADOC Pamphlet 71-9. Partners in the effort were the Space and Missile Defense Battle Laboratory (SMDBL), the Army Research Laboratory, the Project Director for the IMETS, the Air Force Combat Weather Center, and the Combined Arms Center SWO. The purpose of the experiment was to integrate tactically relevant weather products via the IMETS into the Maneuver Control System (MCS) and to determine the utility of these products to the warfighter. SMDBL was specifically responsible for providing the space technology as well as the administrative and management structure for the effort. Further, SMDBL utilized its Hardware Software Integration Center for systems integration and testing activities. Feedback from the Army Battle Command System and Battlefield Visualization community was very positive. It indicated an appreciation of the joint partnerships formed, a confirmation that the project was "on the right track", and that the BV-ICT would continue to look to the experiment team to mature the integration of digital weather products into ABCS platforms. As a result of the initial success of the experiment, work will continue in FY 1999 with a TRADOC-funded Concept Experimentation Program (CEP) led by

BCBL-Huachuca. The purpose of the CEP will be to advance the visualization of weather impact products on battle command systems. SMDBL will serve as prime developer for the effort.

SMDBL continues its focus on Army experimentation by leading the Tactical Weather initiative in the Joint Contingency Force Advanced Warfighting Experiment (JCFAWE). To be conducted in September 2000, the Tactical Weather leverages advances in the Army's IMETS program together with emerging capabilities from AFW Reengineering into a joint capability for the warfighter. SMDBL will provide administrative leadership as well as two space system capabilities for the experiment. Those capabilities are the Deployable Weather Satellite Workstation (DWSW), which directly acquires and processes telemetry from civilian and military weather satellites, and the Meteorological Automated Sensors & Transceiver (MAST), which collects critical surface weather data and passes the information to users via satellite communications. Not only will the MAST contribute to the JCFAWE program but will be further tested and developed in FY 1999 through a series of experiments to include the III Corps Warfighter, Northern Edge, and Roving Sands. SMDBL has partnered with the AFWA, the Special Operations Command, and Army Intelligence Center to use the MAST as a prototype effort to assist the building of the battlefield weather sensor architecture of the future.